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How Much Noise is Too Much for Southern Resident Killer Whales in the Salish Sea? The Case for a Carrying Capacity Study.

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emerging issues in the

How Much Noise is Too Much for Southern Resident Killer Whales in the Salish Sea?

The Case for a Carrying Capacity Study

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BACKGROUND

The Salish Sea is an international ecosystem shared by British Columbia (BC), Canada and Washington state, USA. The maritime section of the international border bisects the Strait of Juan de Fuca and runs through a maze of islands, eventually landing just south of Vancouver, BC (Figure 1). A busy international shipping corridor that hosts commercial vessel traffic, including fuel tankers, fishing boats and barges overlays much of the international border in the marine waters (Figure 2). In the Salish Sea, vessel noise and disturbance represent particular concerns in the context of conservation of the endangered Southern Resident killer whale (SRKW).

Vessel noise and disturbance can change the behavior of many marine animals which can result in the disruption of biologically important processes. Although underwater noise is generated by many sources, including construction and military exercises, vessel noise is now the dominant source of ambient anthropogenic noise throughout much of the world's oceans, and the Salish Sea is no exception. Noise generated by vessel propulsion can mask sounds that marine mammals use to communicate, navigate, find mates, and food (e.g., Clark et al. 2009, Veirs et al. 2016, Gabriele et al. 2018).

The SRKW population was heavily depleted by a historical live-capture fishery (1964-1976) for display in aquaria. The population dropped to approximately 71 individuals by 1976. It recovered to 98 individuals in 1995 but

Figure 1. Salish Sea jurisdictions and international border (Flower 2021).

declined to 73 individuals by 2022. The population is listed under Canada's Species at Risk Act (SARA) and the United States' Endangered Species Act (ESA).

Most marine mammal populations recover after the cessation of hunting (Lotze et al. 2011). For instance, many humpback whale

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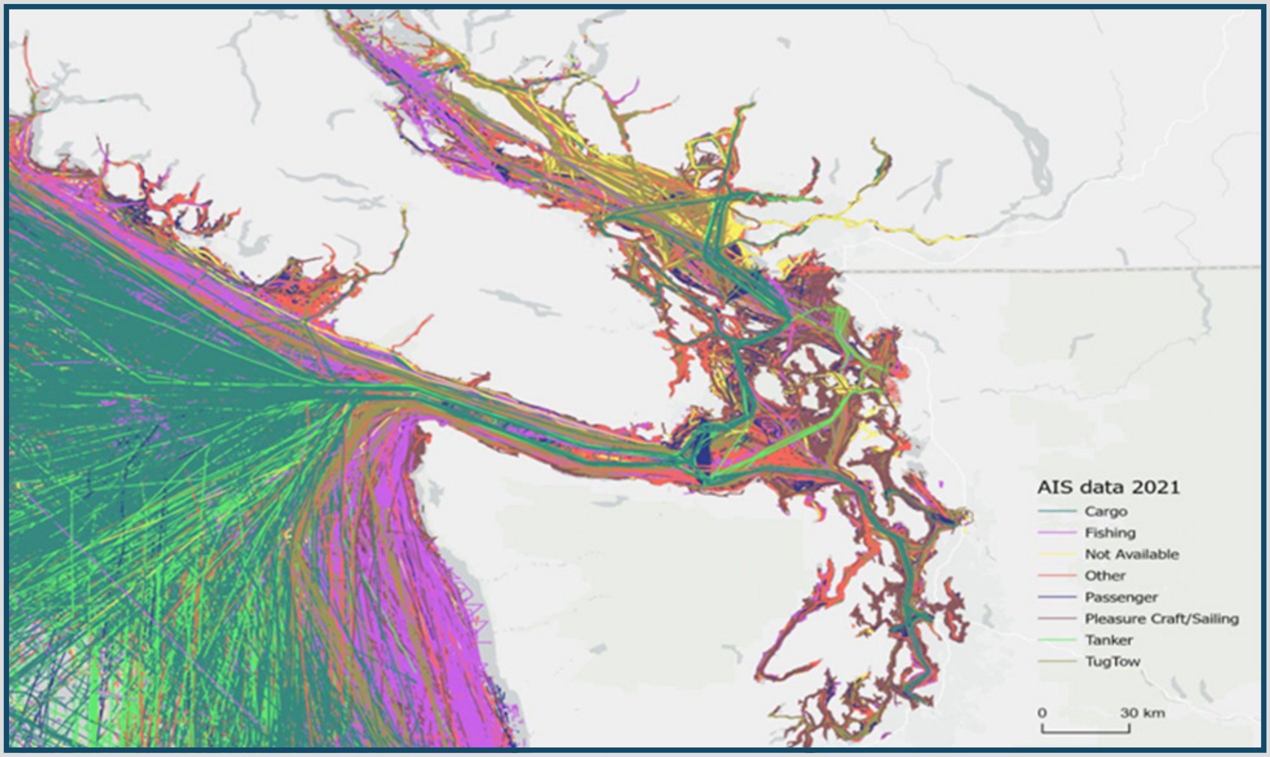

Figure 2. Vessel tracks in the Salish Sea during the calendar year 2021. Equipped vessels transmit information on ship identity, cargo, location, speed, and destination over an automatic identification system (AIS). The AIS data were downloaded from marinecadastre.gov, and points were connected to form tracks using the U.S. Coast Guard Navigation Center's AIS TrackBuilder Tool v1.0 (for ArcGIS Pro).

populations, along with eastern gray whales, have recovered to pre-exploitation levels over the last few decades. Bounties were placed on harbor seals until 1960, and most populations approached or exceeded pre-harvest size in the decades after the hunt was banned. Northern elephant seals were declared extinct in the 1880s, but a relict population numbering approximately 200 individuals in the 1920s is approaching 200,000 individuals today. The initial decline in SRKW numbers can be attributed directly to the unsustainable levels of removals during the live-capture hunt.

Why are SRKW, unlike so many other marine mammal populations, failing to recover to pre-exploitation levels? Factors governing the rate of recovery of marine mammal populations are complex (Lotze et al. 2017), and some evidence is emerging that highly-social toothed whales and dolphins (including killer whales) are inherently less resilient to over-exploitation than seals, sea lions, and baleen whales (Wade et al. 2012).

Recovery plans in both US and Canada recognize three main threats to the survival and recovery of SRKW: availability of Chinook salmon (the orcas' preferred prey); vessel noise and disturbance (which can disrupt SRKW foraging and thereby reduce the proportion of available prey that is accessible to the whales); and contaminants. Of these three main threats, reducing vessel noise and disturbance is among the most tractable. Whereas increasing prey availability for SRKW is of primary importance, it will take years before salmon populations (with breeding cycles between 3-5 years) begin to recover. While that necessary work is taking place to increase Chinook salmon abundance, reductions in ocean noise can serve as a synergistic mitigation measure providing immediate benefits to the whales.

Although these threats have been known since 2001, only recently have attempts been made to quantify the level of importance of these factors in driving SRKW population dynamics and to quantify how much mitigation would be needed to reach recovery objectives (e.g., National Marine Fisheries Service target of 2.3% annual population growth for 28 years). Lacy et al. (2017) combined all three threats in a population viability analysis (PVA). That analysis showed that prey limitation was the biggest factor in SRKW recovery, followed by vessel noise and disturbance. Contaminants, specifically the effect of PCB concentrations on calf survival, had the least influence on SRKW population growth, but the authors recognized that the model ignored the effects of contaminants other than PCBs, and vital rates other than calf survival. The PVA by Lacy et al. (2017) concluded that, based on the best available science at that time, recovering the SRKW population would require a 30% increase in availability of Chinook salmon over long-term average abundance of salmon.

Perhaps more importantly, it also showed that *even greater* recovery could be achieved if a combined approach was used where Chinook salmon availability in the environment was increased by 15%, as well as increasing accessibility (foraging time/efficiency) of killer whales by reducing acoustic disturbance by 50%. Veirs et al. (2018) estimated that a 50% reduction of vessel noise in the Salish Sea could be achieved by targeting the noisiest 15% of the shipping fleet. These studies show how impactful lowering vessel noise and disturbance can be, and further emphasize the importance of noise reduction as part of the plan for SRKW recovery.

In 2018, Governor Inslee (WA) created a Southern Resident Orca Task Force to gather the best available information to guide management actions that support SRKW recovery. The Task Force reviewed the science and used Lacy's results as an informal guideline to gauge whether the management actions being discussed had the potential to make a difference in SRKW recovery. They recognized the synergistic effect of both increasing salmon abundance *and* reducing vessel noise and disturbance that would provide a significant boost to increasing prey availability. This was a consequential decision as it recognized that a reduction of noise levels was a more precautionary target (i.e., "net ecological gain"). Previously, managers were assessing environmental impacts of proposed industrial developments (e.g., pipelines, liquified natural gas terminals, port expansions) with an eye to ensuring that the resulting shipping would cause "no net increase" in noise levels. However, questions remain about which noise should be mitigated and by how much? Should it be based on absolute loudness, duration of exposure, or a combination of these or other factors?

Both the US Endangered Species Act and Canada's Species at Risk laws have a role in protecting SRKW *and* their critical habitats. Habitat degradation is not just physical alteration. Vessel noise and disturbance reduce habitat quality for species like SRKW (Williams et al. 2021a). For example, Canada includes ocean noise explicitly as a threat to SRKW critical habitats in the Salish Sea in SARA; however, acoustic aspects of SRKW critical habitat are not named explicitly under the US ESA. From a transboundary perspective, there are similar regulations, voluntary measures, and guidelines on each side of the border aimed at protecting SRKW, but they are not the same.

What are the impacts on a species that travels freely across the border if different mitigation measures are adopted on either side? Management of the Salish Sea is complex (Jones et al. 2021) and overseeing activities that generate underwater noise and disturbance provides an example of that complexity, in a transboundary, multijurisdictional setting.

There are two categories of vessels, each regulated in a different way with regards to wildlife in general, and SRKW in particular. Some vessels target the whales and follow them at varying distances (e.g. recreational boaters, commercial and non-commercial whale watching, research, education, and enforcement vessels). Both countries have prioritized efforts to reduce the impacts of these vessels that seek out SRKW with new laws in place to increase the distance between boats and orcas. Research is ongoing to measure whether whale watching regulations are sufficient to allow SRKW to hunt successfully (Holt et al. 2021).

The other vessel category includes commercial ships (e.g., tankers, fishing vessels, and ferries) which do not target the whales, however they do raise the anthropogenic ambient noise levels and often travel through or near critical SRKW habitat. Some investments have been made to reduce vessel noise and disturbance managed by the public sector (BC Ferries, WA

Cargo ship in the Strait of Juan de Fuca, seen from Pender Island, BC. Credit: Ginny Broadhurst.

State Ferries). During a 2-month trial period in 2017, the Port of Vancouver's Enhancing Cetacean Habitat and Observation (ECHO) Program voluntary slowdowns in Haro Strait had wide industry support. Ambient noise measurements showed a median broadband noise decrease at Lime Kiln of 2.5 dB (44% reduction in acoustic intensity) and for higher amplitude levels of the broadband noise distribution, a decrease of 1.4 dB (28% reduction in acoustic intensity) (Wood et al. 2018, Joy et al. 2019). This suggests important benefits to SRKW by reducing 'potential lost foraging time' (Joy et al. 2019).

Concurrent, land-based behavioral observations of SRKW showed that as noise levels received by the whales increased, SRKW that were already foraging were more likely to stop, and SRKW that were not foraging were less likely to start in the first place, resulting in reduced time available for SRKW to find food (Williams et al. 2021b). This behavioral response suggests that management efforts that reduce vessel noise level and disturbance will increase the proportion of time the whales can spend foraging if prey are available (Williams et al. 2021b). Programs like ECHO and Washington Maritime Blue's Quiet Sound are being implemented in various parts of the Salish Sea and include mitigation measures like voluntary ship slow-down areas and moving ships farther from key SRKW foraging areas. These measures will have positive impacts by reducing vessel noise and disturbance to the whales.

While these management measures are laudable, there is still much work to be done to define success and reduce underwater noise to some biologically meaningful target. It is difficult to define the level at which noise related habitat degradation becomes destructive, but there are many lines of evidence that suggest we may have already passed that point for SRKW (Williams et al. 2021a). And there is still no clear definition of how much is too much noise for the health of SRKW.

Meanwhile, there are proposed developments on both sides of the border that would *increase* the volume of shipping in the region and amplify the ecological concerns already present (Gaydos et al. 2015). Some have argued that noise levels were higher in some locations, like Puget Sound, in the 1990s when SRKW were doing better. But there are many other factors that are important in the health of SRKW, and shifting baselines can confound our ability to compare across time periods equally. A recent study revealed that inbreeding depression is limiting SRKW population growth and the population will further decline if genetic isolation and typical environmental conditions continue (Kardos et al. 2023). It may be that the current SRKW population is less resilient to impacts from vessel noise and disturbance due to a variety of other factors and long-term cumulative impacts.

What noise levels reduce SRKW ability to effectively hunt for prey, or hear pod-specific vocalizations when choosing a mate? What is the limit and have we already reached that point? The challenge of managing vessel noise and disturbance is a multi-layered conundrum given the multiple laws, jurisdictions, and management entities between two countries. And as the SRKW population has declined from 98 to 73 individuals, showing no sign of recovery, there is an urgent need to quantify the noise level that can support SRKW recovery.

NEXT STEPS

The question we need to ask, and answer, is what is the carrying capacity of the Salish Sea for underwater vessel noise? In other words, what amount of vessel noise is acceptable, while at the same time allowing marine life to maintain healthy populations? A dedicated study to determine what level of vessel noise would exceed the allowable harm limits for SRKW is possible. There are already measurements estimating how many individuals can be removed while still maintaining population stability, such as potential biological removal or PBR. However, the effects of noise are often sublethal, causing reductions in killer whale foraging efficiency, which in turn cause the mathematical equivalent of exceeding PBR through premature deaths and missed pregnancies. Understanding how to possibly prevent, or reduce, those losses is a proactive way forward. A carrying capacity study would build mathematical models to predict the level of noise-induced impacts on foraging behavior that could lead to sublethal effects. This must be based on current research of both prey and predator biology/ecology and the relationship between anthropogenic disruption and demographic consequences.

A previous study, based on well-documented inter-annual variability in Chinook salmon abundance and killer whale demography (Ford et al. 2010, Ward et al. 2009), showed that a resident killer whale population could only withstand the anthropogenic disruption of 5-10% of foraging opportunities/time before the population would experience demographic consequences that exceed PBR (Williams et al. 2016). There is evidence that these foundational relationships between prey availability and SRKW demographics are changing (Hilborn et al. 2012). An update on these relationships is required to conduct a carrying capacity study with models based on the most up to date information. For an ecosystem-level perspective, this type of model should be used for other species where appropriate. What level of noise is 'too much' will differ between species, and the survival of SRKW is also dependent on the many factors that contribute to a healthy ecosystem.

For management purposes, a carrying capacity study represents the robust analysis needed to guide the setting of a goal for vessel noise. With that information, the type of mitigation measures that will best reach that outcome can be chosen and implemented. For example, a limit on vessel noise levels could be set that allows no more than X% reduction in acoustic communication space, or to manage noise levels during certain times of year and/or in habitats that minimize behavioral disturbance of killer whales (e.g., Williams et al. 2014).

Ultimately, these measures need to not just be coordinated, but be equally at the right levels, across the border. Lowering vessel noise and disturbance on only one side of the border will likely lead to a lower probability of SRKW recovery, just as managing only one of two fisheries with significant bycatch levels leads to lower probability of achieving conservation management goals (Punt et al. 2020). As we continue the critical work of increasing Chinook salmon abundance, conducting a carrying capacity study of shipping noise in the Salish Sea along with transboundary collaboration on mitigation measures are actions we can take *now* that will provide benefits to SRKW and other marine life. Together these two approaches are important steps for SRKW recovery, and we hope that this paper can help to start the conversations necessary to move forward with this work.

Southern Resident killer whale surfacing in the Salish Sea. Credit: Joe Gaydos, SeaDoc Society

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Salish Sea from space, NASA 2021

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